CCTV Revisited: Face Analysis Under Challenging Conditions

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Problem

Motivation: It is difficult to obtain meaningful data from poor resolution images, especially given challenging conditions such as motion blur, saturation, sensor noise, pose and illumination changes. Although some studies provide questionable routes to analysing this sort of poor input, thus far very little research has been conducted on such difficult data.

Hypothesis: Landmarks (reference points) and edges provide a strong cue for estimating 3D face shape from 2D images.

Novelty: We adapt the ICP algorithm for use in fitting a 3DMM to image edges automatically. This is the first approach that uses hard model/edge correspondences and leads to an algorithm that is both efficient and robust.

3D Morphable Model

A 3D Morphable Model is a deformable mesh whose shape is determined by the shape parameters \( \alpha \in \mathbb{R}^S \). Shape is described by a linear model learnt from data using Principal Components Analysis (PCA). So, the shape of any object from the same class as the training data can be approximated as:

\[
s(\alpha) = P\alpha + \bar{s},
\]

where \( P \in \mathbb{R}^{3N \times S} \) contains the \( S \) principal components, \( \bar{s} \in \mathbb{R}^{3N} \) is the mean shape and the vector \( s(\alpha) \in \mathbb{R}^{3N} \) contains the coordinates of the \( N \) vertices, stacked to form a long vector:

\[s = [x_1 \ y_1 \ z_1 \ldots x_N \ y_N \ z_N]^T.\]

Method

Edges are an attractive feature to exploit because they are relatively insensitive to changes in illumination and camera parameters. They also convey shape and pose information in a rather direct manner.

Our approach is as follows:

1. Compute a binary edge map from the input image.
2. Given an initial estimate of the shape and pose of the face, compute which vertices lie on the occluding boundary of the estimated shape.
3. For each projected edge vertex, find the closest image edge pixel. This can be done efficiently by storing the image edge pixels in a Kd-tree.
4. Filter the correspondences by removing matches where the distance to the closest edge pixel is larger than a threshold.
5. The edge correspondences provide new 2D landmarks. Return to step 2 with the new shape and pose estimates.

Algorithm

**Algorithm 1**: Basic algorithm employed to fit a 3D Morphable Model to a 2D image using known correspondences.

**Data**: 3D Morphable Model, 2D image, Reference points

**Result**: Face model fitted to 2D image

1. Initialize pose parameters;
2. for \( M \) iterations do
   3. Estimate pose parameters whilst keeping shape parameters fixed;
   4. Estimate shape parameters whilst keeping pose parameters fixed;
3. end
4. Perform non-linear bundle adjustment on shape and pose parameters simultaneously;

Results

We propose an approach inspired by the iterated closest point (ICP) algorithm, based on computing hard correspondences between model vertices and edge pixels. Three example scans from Basel Face Model fitted using our method are shown below.

<table>
<thead>
<tr>
<th>Face Image</th>
<th>Base Model</th>
<th>Fitted Model</th>
<th>Texture Sampling</th>
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References


Source